2-2012

Overview of Beranek & Work's 1949 Paper on
"Sound Transmission through Multiple Structures
Containing Flexible Blankets"

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Old Meets New:

An Overview of Beranek & Work’s 1949 Paper “Sound Transmission through Multiple Structures Containing Flexible Blankets”

Ryan Schultz
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20 August 2012
Introduction

Motivations

Describe the structure & the individual elements

Discuss measurement method, significance of the work and conclusions

Present TL predictions for single elements & multi-layered systems and show effect of varying key parameters
Why?

**Predict Barrier Performance**
- TL of a structure consisting of several acoustic elements

**Smarter Design Choices**
- Which elements matter most?
- Does the order of elements matter?
- How do I best utilize cost, weight, & space budgets?

**Better Designs**
- Lighter
- More Economical
- Higher Performance
Structure Description

Panel 1

Incident Sound

Panel 2

Air Space

Blanket

Blanket

Source

Receiver
Individual Elements

- **Panel**
  - Attributes:
    - Mass per unit area

- **Air Space**
  - Attributes:
    - Depth

- **Blanket**
  - Attributes:
    - Flow Resistivity
    - Porosity
    - Structure Factor
    - Mass / unit area
    - Stiffness
    - Depth
Pressure Ratio Expressions

\[ Z_1 = \rho c \coth(j \omega l / c + \psi) \]
\[ Z_5 = \rho c \]

\[ \frac{p_0}{p_1} = 1 + j \omega \sigma_1 / Z_1 \]

\[ \frac{p_0}{p_5} = \frac{p_0}{P_1} \cdot \frac{p_1}{p_2} \cdot \frac{p_2}{p_3} \cdot \frac{p_3}{p_4} \cdot \frac{p_4}{p_5} \]
Pressure Ratio Expressions

\[ p_0 = e^{-j k_0 x} + Re^{j k_0 x} \]

\[ v_0 = \frac{1}{\rho c} (e^{-j k_0 x} + Re^{j k_0 x}) \]

Constraint equations at each interface

Solve the set of equations for the wave coefficients
Complete Structure: 5

Diagram showing a structure with labels L, d₁, and an inset graph showing TL (transmission loss) vs. frequency for different R₁ values.
Design Considerations

Effect of Flow Resistivity

Effect of Panel 1 Area Density
Design Considerations

Effect of Air Space Width

Effect of Blanket Thickness

![Graph showing the effect of air space width on TL (dB) vs. Frequency (Hz)]

![Graph showing the effect of blanket thickness on TL (dB) vs. Frequency (Hz)]
Experimental Considerations

Theory:

- Normal incidence plane waves
- Unconstrained elements of infinite lateral extent

Reality:

- Finite-sized panels
- Mounting creates edge constraints
- Flexural waves in the panels
- Difficulty obtaining purely-planar incident waves
- Existence of flanking paths
Experimental Considerations

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Experimental Considerations

**Theory:**
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**The issue of flexural waves in the panel are addressed by adding sheets of mica to the panels for damping**

**Transverse waves in the air space ahead of the structure are minimized in the experiment by using fiberglass between the loudspeaker sources**
Significance

Ability to predict TL of complicated systems

Basic approach can be modified to accept more complicated elements, structures

The work has been cited by many authors in the acoustics community: Bolton et al., Cummings et al., Kang, Lauriks et al., Mulholland et al., …

Other authors have utilized more complicated element types, layered systems

Many real-world applications

Aircraft

Offices & Residential

Cars & Trains
Conclusions

Presented a theory that uses the impedances of various elements to compute acoustic pressure ratios

Predictions matched well with measurements

Fibrous blankets provide a resistive component which reduces the sharpness of the dips at high frequencies

TL is affected by different design criteria at different frequencies

A resistive element is necessary to decouple the two impervious panels & reduce the effect of the M-A-M resonances

Constraints play a significant role in measurement-theory agreement; care must be taken
Thank You!

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Simplified Structures: 0 & 1

0

1

\[ d_1 \]

\[ L \]

\[ L = 2.5 \text{ cm} \]
\[ L = 5.0 \text{ cm} \]
\[ L = 15.0 \text{ cm} \]

\[ R_1 = 10 \]
\[ R_1 = 25 \]
\[ R_1 = 50 \]
\[ R_1 = 100 \]
Simplified Structures: 0 & 1

![Diagram of structures 0 and 1]

![Graphs showing TL vs. Frequency for structures 0 and 1]